National Aeronautics and Space Administration

Atmospheric Pressure Plasma Jet as a Dry Alternative to Inkjet Printing in Flexible Electronics

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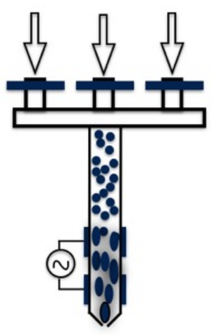
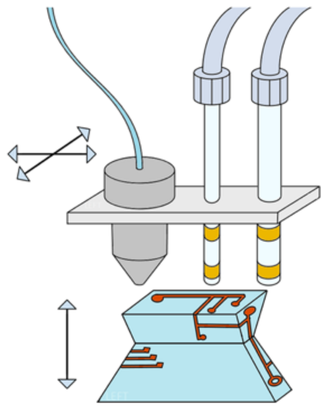
Abstract

We have developed an atmospheric pressure plasma jet printing system that works at room temperature to 50 deg C unlike conventional aerosol assisted techniques which require a high temperature sintering step to obtain desired thin films. Multiple jets can be configured to increase throughput or to deposit multiple materials, and the jet(s) can be moved across large areas using a x-y stage. The plasma jet has been used to deposit carbon nanotubes, graphene, silver nanowires, copper nanoparticles and other materials on substrates such as paper, cotton, plastic and thin metal foils.

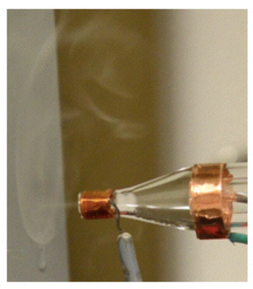
Plasma Jet Multi-Material Printer



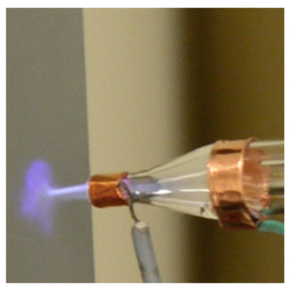
In-situ tailoring/printing



In-line additive manufacturing

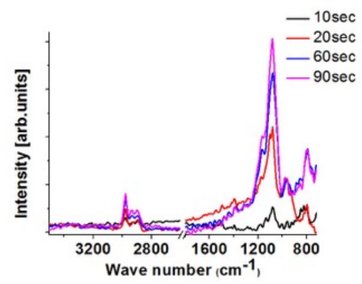


Plasma Off

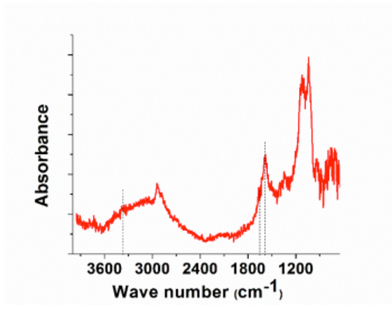


Plasma On

Low & High K Dielectric Coating

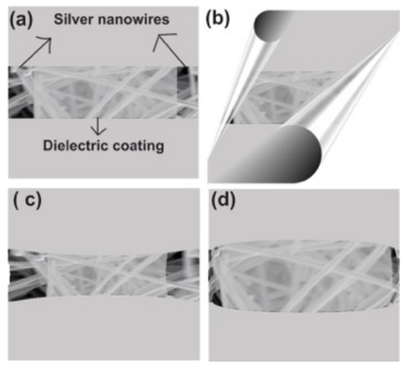


Silicon di oxide coating



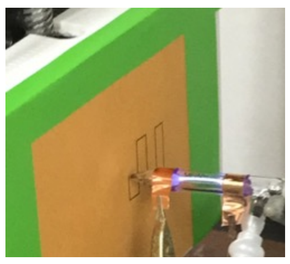
Nitrogen-incorporated silicon oxide coating

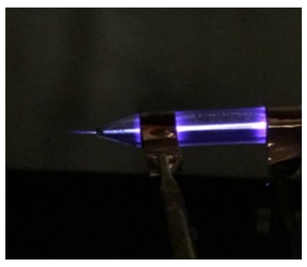
- Nanocolloids, organic materials etc. transported as aerosol by carrier gas
- Precise control over thickness and morphology
- Ability to tailor material properties in situ (chemical, electronic)
- Can be combined as an in-line manufacturing process in additive manufacturing



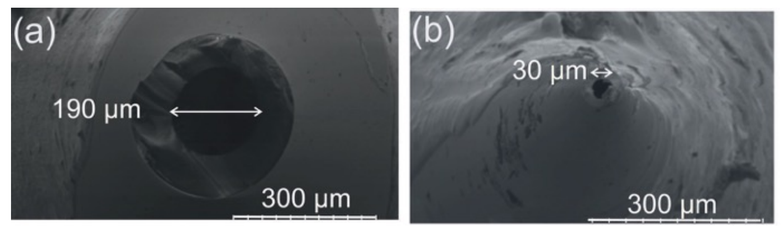
Thin gate dielectric, passivation layer in microelectronics
Optical waveguides (varying refractive index)

Plasma Jet Printed Electronics

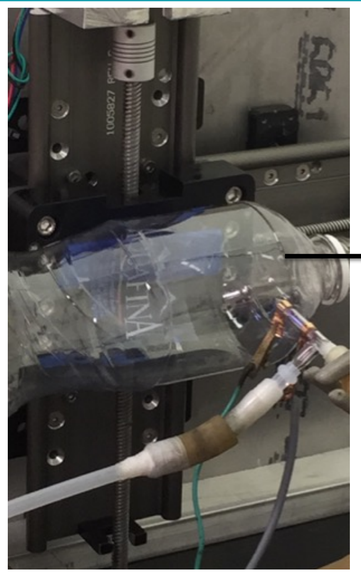


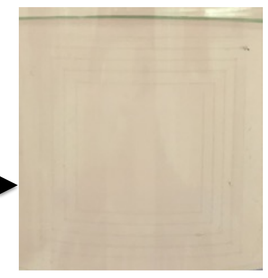


Plasma Jet p

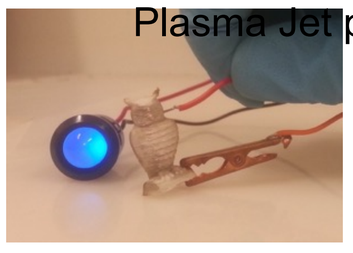


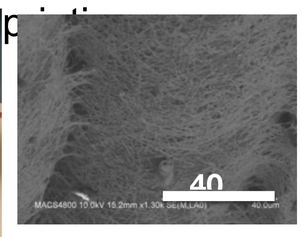
Scanning electron microscopic image of Nozzle

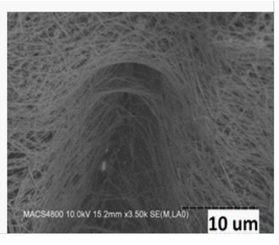




Plasma printed antenna structure on PET bottle

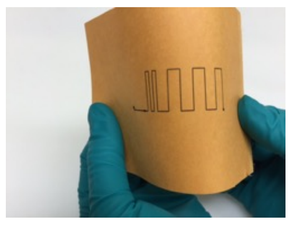






Silver nanowires on 3D printed ABS plastic

Copper on poly imide

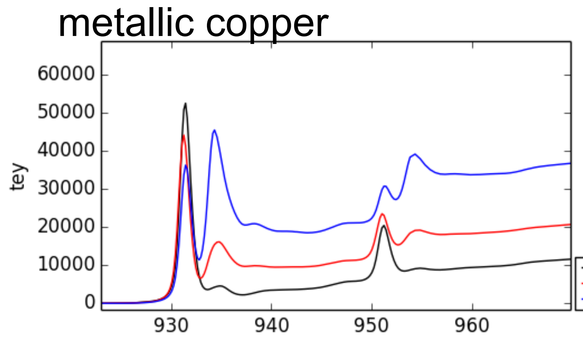


On paper

On PET bottle

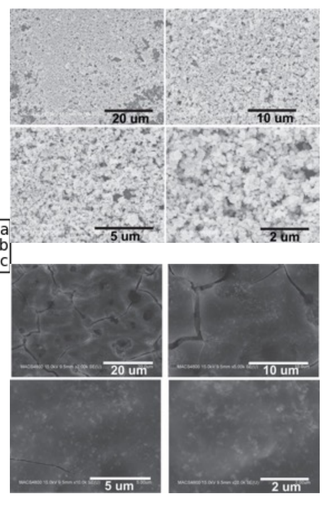
In-situ Tailoring of Material Properties

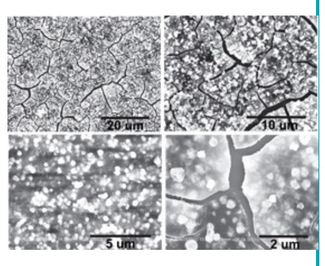
In-situ reduction of Cu2+ to metallic copper

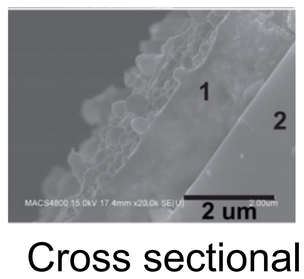


Cu L edge XAS[mono]
No post processing, No pre-post thermal treatment
Printed using same colloid

Controlled surface characteristics







Cross sectional SEM of Cu(1) on Silicon(2)

Contacts & Reference

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(1)Three US Patent applications pending
(2) Ram P. Gandhiraman et al., *Applied Physics Letters*. **2016**, 108, 123103.
(3) Ram P. Gandhiraman et al., *ACS Appl Mater Interfaces*. **2014**, 6, 20860
(4)Ram P. Gandhiraman, Dennis Nordlund, Vivek Jayan, M. Meyyappan, Jessica E. Koehne. ACS Appl Mater Interfaces. 2014, 6, 22751.
(5)https://www.sciencedaily.com/releases/2016/03/160322120038.htm